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RESEARCH

Dynamics of Türkiye's Hazelnut Exports: An Autoregressive Distributed Lag Analysis

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Abstract
This study pursues a dual objective: First, it evaluates the export competitiveness of Türkiye's hazelnut sector over the period 1970–2020 by employing the revealed symmetric comparative advantage index. Second, it investigates the long-run and short-run dynamics between hazelnut exports and a set of macroeconomic and sector-specific determinants, including foreign direct investment, hazelnut export prices, hazelnut production, real effective exchange rates, and terms of trade. To this end, an autoregressive distributed lag bounds testing framework is adopted, enabling the identification of both equilibrium relationships and short-run adjustment mechanisms. The empirical findings confirm the existence of a stable long-run relationship between hazelnut exports and key economic fundamentals, accompanied by significant short-run dynamics. However, foreign direct investment does not exhibit a robust export-enhancing effect, suggesting that capital inflows into the sector have not been effectively translated into increased hazelnut export performance. The results underscore the dominant role of price competitiveness and structural advantages in shaping Türkiye's hazelnut exports.

Keywords *Corylus avellana* · ARDL bounds testing · Comparative advantage · Hazelnut exports · Türkiye

Introduction

Hazelnuts are among the most strategically important nut crops in global agricultural trade, not only because of their nutritional value but also due to their highly concentrated geographical production structure. Despite Türkiye's long-established dominance in both production and exports, the determinants of its hazelnut export performance remain insufficiently understood from an econometric perspective. In particular, how export competitiveness, price dynamics, macroeconomic conditions, and sector-specific factors jointly shape hazelnut exports over the long and short run has not been rigorously quantified. This gap is especially striking given Türkiye's role as the world's leading hazelnut producer and exporter, supplying more than half of global output. Addressing this shortcoming, the present study provides a comprehensive time-series analysis of Türkiye's hazelnut exports by jointly modeling competitiveness and macroeconomic drivers within an autoregressive distributed lag (ARDL) framework over the period 1970–2020.

Hazelnut (*Corylus avellana* L.) is a temperate-climate species that can be cultivated only within a relatively narrow range of suitable ecological conditions. The Southern Caucasus, Anatolia, and the Black Sea basin are widely recognized as the primary centers of origin for hazelnut cultivation (Mehlenbacher 1991; Mehlenbacher and Molnar 2021). Owing to its favorable ecological conditions and its role as a gene center for the species, Türkiye has produced hazelnuts since ancient times and continues to represent one of the most important regions globally in terms of genetic diversity and cultivation intensity (Ozdemir and Akinci 2004; Botta et al. 2020).

Hazelnut production in Türkiye is predominantly embedded in traditional nut cultivation systems and constitutes a critical source of income for small-scale farms, particularly in the Black Sea region (FAOSTAT 2025). While numerous hazelnut varieties are cultivated worldwide, only a limited number combine high yield with superior kernel quality suitable for commercial processing. In Türkiye, cultivars such as 'Tombul', 'Palaz', 'Çakıldak', 'Kalınkara', and 'Sivri' dominate production, with 'Tombul', 'Palaz', and 'Çakıldak' accounting for the bulk of commercial out-

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put due to their favorable technological and quality attributes (Ayfer et al. 1986).

From a nutritional standpoint, hazelnuts are highly valued for their dense energy content and rich biochemical composition, including unsaturated fatty acids, particularly oleic acid, proteins, carbohydrates, minerals, vitamins, and bioactive compounds (Ozdemir and Akinci 2004; Alasalvar et al. 2006). These attributes have contributed to steadily rising global demand, especially from the confectionery and food processing industries.

According to statistics from the Food and Agriculture Organization of the United Nations (FAO), hazelnuts constitute a substantial share of global nut production. In 2023, global hazelnut output reached approximately 1.13 million metric tons, with Türkiye accounting for around 650,000 metric tons, corresponding to 57.77% of total world production (FAOSTAT 2025). Türkiye is followed by Italy, Azerbaijan, and the United States. In parallel with its production dominance, Türkiye is also the world's leading hazelnut exporter, supplying the majority of global export volumes. In 2023, Türkiye exported approximately 153,668 metric tons of hazelnuts, ranking first globally (FAOSTAT 2025). Nevertheless, fluctuations in yield, price volatility, and structural inefficiencies continue to constrain the sector's export potential, underscoring the need for a systematic analysis of the underlying drivers of export performance.

Against this backdrop, the present study evaluates the competitiveness of Türkiye's hazelnut sector and investigates the long- and short-run determinants of hazelnut exports (hazelnut export volume [VEXP]) using annual data spanning 1970–2020. Specifically, the analysis examines the roles of foreign direct investment (FDI), hazelnut export prices (PRC), hazelnut production (PROD), the real effective exchange rate (REER), revealed symmetric comparative advantage (RSCA), and terms of trade (TOT). The ARDL bounds testing approach to cointegration is employed, enabling the simultaneous estimation of long-run equilibrium relationships and short-run adjustment dynamics within a unified framework.

Although the ARDL methodology has been widely applied in export and agricultural trade studies (Ramphul 2013; Akinbode and Ojo 2018; Dube et al. 2018; Ghimire et al. 2021; Khan et al. 2021; Ceesay and Fanneh 2022), empirical evidence focusing specifically on strategic perennial crops such as hazelnuts remains scarce. Existing studies on Turkish agricultural exports largely concentrate on aggregate trade flows or individual horticultural products such as apples or olives (Sertoglu and Dogan 2016; Orman and Dellal 2021; Kilic and Turhan 2023; Sarica et al. 2023), leaving hazelnut exports relatively underexplored despite their macroeconomic importance. Several studies have examined the determinants of agricultural exports and export performance in Türkiye using time-series and panel data approaches, with particular emphasis on exchange rates, prices, and production capacity. For instance, Sertoglu and Dogan (2016) and Orman and Dellal (2021) investigate the relationship between exchange rate dynamics and agricultural exports using bounds testing and ARDL methodologies, while Kilic and Turhan (2023) focus on specific horticultural products. These studies generally confirm the importance of price competitiveness and macroeconomic conditions in shaping export outcomes; however, they do not explicitly address perennial nut crops characterised by highly concentrated production structures, such as hazelnuts.

Empirical evidence focusing specifically on hazelnut exports has expanded in recent years, yet remains limited in terms of country-specific time-series analyses for Türkiye. Dağ and Sarica (2025) analyze global hazelnut export dynamics using a panel nonlinear autoregressive distributed lag (NARDL) framework, incorporating environmental and economic factors such as CO_2 emissions, yield, export prices, and exchange rate fluctuations across major exporting countries. Their findings highlight the sensitivity of hazelnut exports to both environmental and macroeconomic conditions, providing valuable insights from a cross-country perspective. Similarly, Sarica et al. (2023) evaluate the competitiveness of Türkiye's apple sector using the RSCA index and trade-related indicators such as apple exports, foreign direct investment, apple export price, apple production, the competitiveness of the apple sector, and terms of trade variables, emphasising Türkiye's dominant position in international apple markets. Despite these contributions, existing studies primarily rely on panel data frameworks or focus on global competitiveness indicators, rather than examining the dynamic export behavior of Türkiye within a country-specific time-series context. Moreover, the integration of export competitiveness measures, such as RSCA, together with macroeconomic and sector-specific variables within a single-country ARDL framework remains largely unexplored. To the best of our knowledge, no previous study has jointly analyzed Türkiye's hazelnut exports by combining production capacity, price dynamics, trade competitiveness, foreign direct investment, and exchange rate movements within an ARDL model over a long historical period. By addressing this gap, the present study contributes to the literature by offering a comprehensive assessment of both the long-run and short-run determinants of Türkiye's hazelnut export performance.

By integrating export competitiveness measures with macroeconomic and sector-specific variables within a dynamic ARDL framework, this study contributes to the literature in three key ways. First, it provides the first long-horizon econometric assessment of Türkiye's hazelnut export determinants. Second, it explicitly incorporates export competitiveness through the RSCA index, allowing for

a nuanced evaluation of comparative advantage dynamics. Third, it offers policy-relevant insights for producers and decision-makers aiming to enhance export performance and stabilize the hazelnut sector in an increasingly competitive global market.

Materials and Methods

Data and Variable Construction

This study investigates the determinants of hazelnut exports in Türkiye over the period 1970–2020 using annual time-series data. The empirical analysis incorporates VEXP as the dependent variable and a set of macroeconomic and sector-specific explanatory variables, including FDI, PRC, PROD, the REER, the RSCA index, and TOT. The selection of explanatory variables in the model is guided by both theoretical considerations and empirical evidence from the agricultural trade literature. VEXP is assumed to be influenced by PROD, PRC, trade competitiveness, macroeconomic conditions, and external investment flows. PROD is included to capture supply-side capacity effects, as higher production levels are expected to enhance export availability and continuity, implying a positive relationship with exports. Export prices are incorporated to reflect price competitiveness; *ceteris paribus*, higher export prices may reduce export demand due to price sensitivity in international markets, suggesting a negative relationship, although quality improvements and market power may offset this effect in certain periods.

The RSCA index is included as a structural indicator of international competitiveness. A higher RSCA value reflects a stronger comparative advantage and is therefore expected to exert a positive influence on export performance. The REER is employed to account for price competitiveness and external price movements; an appreciation of the domestic currency is generally expected to weaken exports by increasing relative export prices, while a depreciation may stimulate export volumes. TOT are included to capture the relative movement of export and import prices; their impact on exports is theoretically ambiguous, as improvements in terms of trade may either enhance export revenues or reduce export volumes through income and substitution effects.

FDI is incorporated to capture potential technology transfer, productivity enhancement, and integration into global value chains. In the context of agricultural and agri-food exports, FDI may positively affect export performance by improving processing capacity, logistics, and quality standards. However, the effect of FDI may also be negative if investment flows are directed towards non-export-oriented segments of the economy or concentrate on domestic market activities rather than export production. Given these opposing mechanisms, the expected sign of the FDI coefficient remains theoretically ambiguous, and its net impact is determined empirically within the ARDL framework.

Data on hazelnut export value (US$), export volume (metric tons), and production quantity (metric tons) were obtained from the Food and Agriculture Organization database (FAOSTAT 2025). Terms of trade data were sourced from the Organisation for Economic Co-operation and Development (OECD 2025), while REER series were retrieved from the Central Bank of the Republic of Türkiye (CBRT 2025). Following standard definitions, the terms of trade are measured as the ratio of the export price index to the import price index; an increase in this ratio reflects an improvement in a country's purchasing power, as higher export prices relative to import prices enable the acquisition of a greater volume of imports for a given level of exports (OECD 2025).

Foreign direct investment data were obtained from the World Development Indicators of the World Bank (World Bank 2025). The hazelnut export price (US$/kg) was computed as the ratio of total export value to export volume, consistent with conventional practice in the empirical export literature.

$$\text{Export price} = \frac{\text{Value of export}}{\text{Volume of export}} \tag{1}$$

The RSCA index was computed following the methodology proposed by Dalum et al. (1998), which was developed to address the asymmetry and scaling limitations inherent in Balassa's (1965) revealed comparative advantage (RCA) index. The theoretical foundation of comparative advantage dates back to Ricardo (1817), while Balassa (1965) operationalized the concept by introducing an index-based approach that infers relative advantage or disadvantage from observed trade patterns. Since then, the RCA framework has been extensively employed to assess countries' specialization structures, productivity differentials, and competitiveness in international markets (Rossato et al. 2018).

To improve interpretability and ensure symmetry around zero, Dalum et al. (1998) transformed the RCA index into the RSCA measure, which is defined as:

$$RSCA_i^j = \frac{RCA_i^j - 1}{RCA_i^j + 1} \tag{2}$$

where the underlying RCA index is given by:

$$RCA_i^j = \frac{\left(x_i^j / PX_i\right)}{\left(PX_w^j / PX_w\right)} \tag{3}$$

In these expressions, $RSCA_i^j$ denotes the revealed symmetric comparative advantage of country i in product j; x_i^j represents the export value of hazelnuts (j) by country i; PX_i refers to the total agricultural export value of country i; PX_w^j denotes total world hazelnut exports; and PX_w represents total world agricultural exports.

The RSCA index is bounded between –1 and +1, facilitating a symmetric interpretation. Positive RSCA values ($0 < RSCA \leq 1$) indicate the presence of an RCA and net exporter status, whereas negative values ($-1 \leq RSCA < 0$) signify a revealed comparative disadvantage and net importer position. This symmetric structure enhances cross-country and intertemporal comparability relative to the traditional RCA measure.

In addition to the quantitative analysis, a comprehensive review of national and international academic articles, policy reports, and scholarly books was conducted to contextualize the empirical findings and strengthen the analytical framework of the study.

ARDL Model Specification and Estimation

This study employs the ARDL bounds testing approach developed by Pesaran et al. (2001) as its primary econometric framework. Conventional cointegration techniques, such as those proposed by Engle and Granger (1987) and Johansen (1988), require all variables to be integrated of the same order, typically I(1), which restricts their applicability in empirical settings involving mixed integration properties. The ARDL bounds testing methodology overcomes this limitation by allowing cointegration analysis irrespective of whether regressors are stationary at levels I(0) or first differences I(1), provided that none of the series is integrated of order two.

The empirical strategy proceeds in several stages. First, the time-series properties of all variables are examined to determine their order of integration using the Augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) and the Phillips–Perron (PP) test (Phillips and Perron 1988). Second, the existence of a long-run equilibrium relationship among the variables is assessed through the ARDL bounds testing procedure proposed by Pesaran et al. (2001). Third, conditional on the confirmation of cointegration, both long-run coefficients and short-run dynamic adjustments are estimated within an error correction framework. Finally, the stability of the estimated parameters is evaluated using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests developed by Brown et al. (1975) to detect potential structural instability over the sample period.

A key advantage of the ARDL bounds testing approach lies in its reliance on an unrestricted error correction model (UECM), which simultaneously captures short-run dynamics and long-run equilibrium relationships. Moreover, the ARDL framework yields consistent and efficient parameter estimates even in relatively small samples, making it particularly suitable for long-span annual data (Pesaran et al. 2001). In line with this methodological framework, the stationarity properties of the variables were first examined, followed by the specification and estimation of the ARDL model to test for cointegration.

Accordingly, the empirical model examining the determinants of Türkiye's hazelnut exports is specified as follows:

$$\begin{aligned}\Delta VEXP_t = \beta_0 &+ \sum_{i=1}^{p} \beta_{1i}\,\Delta VEXP_{t-i} + \sum_{i=0}^{q} \beta_{2i}\,\Delta FDI_{t-i} \\ &+ \sum_{i=0}^{v} \beta_{3i}\,\Delta PRC_{t-i} + \sum_{i=0}^{y} \beta_{4i}\,\Delta PROD_{t-i} \\ &+ \sum_{i=0}^{z} \beta_{5i}\,\Delta REER_{t-i} + \sum_{i=0}^{c} \beta_{6i}\,\Delta RSCA_{t-i} \\ &+ \sum_{i=0}^{d} \beta_{7i}\,\Delta TOT_{t-i} + \varepsilon_t \end{aligned} \tag{4}$$

where Δ denotes the first-difference operator; p, q, v, y, z, c, and d represent the optimal lag lengths for each variable; and ε_t is a white-noise error term. The existence of cointegration is tested using the F-statistic derived from the bounds testing procedure. Cointegration is confirmed if the calculated F-statistic exceeds the upper critical bound reported by Pesaran et al. (2001), values falling between the lower and upper bounds yield inconclusive results, while values below the lower bound indicate the absence of a long-run relationship.

Once cointegration is established, the ARDL model is estimated to obtain both long-run parameter estimates and short-run adjustment dynamics. Model adequacy is subsequently assessed through a battery of diagnostic tests, while parameter stability over the sample period is evaluated using the CUSUM and CUSUMSQ statistics. All econometric estimations were conducted using EViews 13 software (EViews 2025).

Results and Discussion

Competitiveness Analysis of Türkiye's Hazelnut Sector

Table 1 reports the RSCA indices of Türkiye's hazelnut sector over selected sub-periods and recent individual years. The consistently high and positive RSCA values provide strong evidence of Türkiye's persistent and pronounced

Table 1 Revealed symmetric comparative advantage indices of the hazelnut sector for Türkiye. (Authors' calculations)

Year	Türkiye
1970–1980	0.977316165
1981–1990	0.969745749
1991–2000	0.973679522
2001–2010	0.974094847
2011–2020	0.964393294
2018	0.962197497
2019	0.961961059
2020	0.956863379

comparative advantage in the global hazelnut market. Across all sub-periods from 1970–1980 to 2011–2020, the RSCA index exceeds 0.96, underscoring the structural and enduring nature of Türkiye's competitiveness in hazelnut exports. Although the RSCA values exhibit a slight downward trend in the most recent years, particularly between 2018 and 2020, the index remains at exceptionally high levels, indicating that Türkiye continues to maintain a dominant export position despite increasing international competition and evolving market conditions. This marginal decline may reflect short-term market adjustments, price fluctuations, or changes in global demand rather than a fundamental erosion of comparative advantage. Overall, the RSCA results confirm that hazelnut exports constitute one of Türkiye's most competitive agricultural sectors, reinforcing the importance of sustained policy support and strategic investment to preserve and enhance this long-standing comparative advantage.

Export Analysis of Türkiye's Hazelnut Sector

Table 2 presents the descriptive statistics of the variables employed in the empirical analysis. Descriptive statistics provide an initial quantitative assessment of the data by summarizing their central tendency, dispersion, and distributional characteristics. Accordingly, key summary measures including the mean, minimum and maximum values, standard deviation, and the Jarque–Bera statistic are reported to characterize the underlying properties of each series prior to model estimation.

Prior to model estimation, a series of preliminary econometric procedures were undertaken to establish the time-series properties of the variables. Specifically, the order of integration was examined using the ADF (Dickey and Fuller 1979) and PP (Phillips and Perron 1988) unit root tests. In both tests, the null hypothesis posits the presence of a unit root in the series. The rejection of the null is based on the absolute value of the test statistic exceeding the corresponding critical value. All variables were tested under specifications including a constant and a constant with a deterministic trend. The results reported in Table 3 indicate that, at levels I(0), all series except for the TOT are non-stationary. However, after first differencing I(1), all variables become stationary at the 1% significance level under both deterministic specifications. These findings confirm a mixed order of integration among the variables, thereby justifying the application of the ARDL bounds testing approach.

In the unit root testing procedure, both intercept-only and intercept-with-trend specifications were initially considered for all variables. The final interpretation of the ADF and PP test results is based on the intercept-only model, as the majority of the series do not exhibit a clear deterministic trend over the sample period. Preliminary visual inspection of the series and descriptive statistics indicate that the variables fluctuate around a constant mean rather than displaying a persistent upward or downward trend.

In such cases, including an unnecessary deterministic trend component may reduce the power of unit root tests and lead to misleading inferences. Therefore, following standard practice in time-series econometrics, the intercept-only specification is preferred for variables without a pronounced deterministic trend. The consistency of the stationarity results across both ADF and PP tests further supports the robustness of this specification choice.

Following the assessment of the unit root properties of the variables, the presence of a long-run relationship between the dependent and independent variables was examined using the ARDL bounds testing approach. To this end, an error correction representation of the model was specified. Given that cointegration results are sensitive to lag length selection (Pesaran et al. 2001), a systematic lag selection procedure was employed, and the maximum lag length was set to four. The model was subsequently estimated using this lag structure, and the F-statistic was computed to test for cointegration. Based on standard model selection

Table 2 Descriptive statistics of the variables. (Authors' calculations)

	VEXP	FDI	PRC	PROD	REER	RSCA	TOT
Mean	561,750.73	0.8043301	4.0543271	434,396.8	0.9860456	0.9719532	109.70671
Maximum	1,640,461	3.6233825	11.459061	800,791	7.0216639	0.9824155	126.92874
Minimum	78,690	0.0194363	1.2059585	166,000	1.151E-05	0.9568634	81.372717
Std. Dev.	376,422.2	0.8459763	2.354793	160,962.79	1.5519089	0.0055116	10.426905
Jarque–Bera	7.1106539	26.49194	11.299236	1.993048	81.109753	2.1365248	1.777036

VEXP Hazelnut exports, *FDI* Foreign direct investment, *PRC* Hazelnut export price, *PROD* Hazelnut production, *REER* Real effective exchange rate, *RSCA* Revealed symmetric comparative advantage, *TOT* Terms of trade

Table 3 Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root test results. (Authors' calculations)

Level	ADF	–	PP	–
Variables	Constant	Constant with trend	Constant	Constant with trend
VEXP	1.4476	–3.8562**	–1.2927	–3.7828**
FDI	–2.1507	–3.5716**	–2.0466	–2.9016
PRC	1.6716	–4.6284***	–1.7528	–3.6541**
PROD	–0.7079	–8.3732***	–3.2329**	–8.3732***
REER	–2.2946	–1.8172	–6.2843	–4.3004
RSCA	–0.7484	–1.7676	–1.9668	–2.5676
TOT	–3.5552**	–3.5807**	–3.5445**	–3.5760**
First difference	ADF	–	PP	–
Variables	Constant	Constant with trend	Constant	Constant with trend
VEXP	–1.9162***	–2.8565***	–19.7136***	–20.6013***
FDI	–5.8634***	–5.7953***	–11.7663***	–11.6291***
PRC	–1.5650***	–4.9299***	–16.8625***	–16.5791***
PROD	–5.3246***	–5.2331***	–34.8484***	–33.6387***
REER	–2.3948***	–0.2304***	–0.7727***	–0.8316***
RSCA	–10.3919***	–10.5208***	–10.7452***	–11.2185***
TOT	–8.3275***	–8.0538***	–12.0038***	–13.0435***

The critical values for ADF and PP tests are –3.465, –2.876, and –2.575 for the intercept model and –4.008, –3.434, and –3.141 for the intercept and trend model at the 1%, 5%, and 10% significance levels, respectively. Maximum lag lengths were set to 4, and optimal lags were selected based on the Akaike Information Criterion (AIC).
VEXP Hazelnut exports, *FDI* Foreign direct investment, *PRC* Hazelnut export price, *PROD* Hazelnut production, *REER* Real effective exchange rate, *RSCA* Revealed symmetric comparative advantage, *TOT* Terms of trade
***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

criteria, the ARDL (1, 2, 4, 0, 1, 0, 0) specification was identified as the optimal model. Table 4 reports the corresponding F-statistic along with the relevant lower and upper critical bounds for the selected ARDL specification.

The bounds testing results indicate the existence of a long-run cointegration relationship between Türkiye's hazelnut exports and the selected explanatory variables, as the computed F-statistic exceeds the upper critical bound at the 1% significance level. Upon establishing cointegration, the ARDL framework allows for the consistent estimation of both long-run coefficients and short-run dynamics. Table 5 reports the diagnostic test results associated with the estimated ARDL model. The findings provide no evidence of heteroskedasticity, serial correlation, or functional form misspecification, and the residuals are found to be normally distributed. Collectively, these diagnostic outcomes confirm the adequacy of the model specification and support the statistical reliability and robustness of the estimated long-run and short-run results.

The long-run parameter estimates obtained from the ARDL framework indicate that Türkiye's hazelnut exports are systematically driven by a subset of key economic

Table 4 F-bounds test results. (Authors' calculations)

	Value	Significance	I(0)	I(1)
F-statistics	6.764007***	10%	2.120	3.230
k	6	5%	2.450	3.610
m	4	1%	3.150	4.430
Selected model	ARDL (1, 2, 4, 0, 1, 0, 0)	–	–	–

k Number of explanatory variables, *m* Maximum number of lag
***Significant at the 1% level

Table 5 Diagnostic test results for the autoregressive distributed lag model. (Authors' calculations)

	F-statistics	χ^2
Breusch–Godfrey serial correlation Lagrange Multiplier test	0.250034	0.6802
Jarque–Bera normality test	0.136041	0.934241
Breusch–Pagan–Godfrey heteroskedasticity test	0.486659	0.9957
Ramsey reset test	1.554763	0.2218

fundamentals. PRC exert a positive and highly significant effect at the 1% level, underscoring the central role of price competitiveness in shaping long-run export performance. In contrast, FDI enters the model with a statistically significant but negative coefficient at the 5% level, suggesting that FDI inflows have not been effectively channeled into export-enhancing activities within the hazelnut sector. The REER and the RSCA index exhibit positive coefficients that are marginally significant at the 10% level, highlighting the relevance of macroeconomic conditions and structural competitiveness for sustaining exports over time. By contrast, PROD and TOT do not display statistically significant long-run effects, implying that supply capacity alone is insufficient to explain export dynamics. Overall, the evidence confirms the presence of a stable long-run cointegration relationship between hazelnut exports and price dynamics, investment patterns, and competitiveness indicators over the 1970–2020 period, in line with theoretical predictions.

Prior to the interpretation of the estimated coefficients, a comprehensive set of diagnostic tests was conducted to assess the adequacy and reliability of the ARDL model. As reported in Table 5, the results of the Breusch–Godfrey serial correlation test, Breusch–Pagan–Godfrey heteroskedasticity test, Jarque–Bera normality test, and Ramsey's Regression Specification Error Test (RESET) indicate no evidence of serial correlation, heteroskedasticity, non-normality, or functional form misspecification. These findings confirm that the estimated model is statistically well specified and free from major econometric problems.

In addition, potential multicollinearity concerns arising from the joint inclusion of the REER and TOT were explicitly examined. Pairwise correlation coefficients among the explanatory variables were computed and did not reveal excessively high correlations that would indicate severe multicollinearity. Therefore, the simultaneous inclusion of REER and TOT does not distort coefficient estimates or undermine inference. Overall, the diagnostic and correlation analyses confirm the robustness of the model and support the validity of the estimated long-run and short-run relationships. It should be noted that the magnitude of the estimated coefficients reflects the original measurement units of the variables rather than model misspecification. Since the variables are expressed in levels and measured in different units (e.g., metric tons, index values, and monetary units), coefficient sizes are not directly comparable across regressors and should be interpreted accordingly (Table 6).

An examination of the short-run estimation results indicates that hazelnut exports respond asymmetrically to changes in key explanatory variables. In particular, PRC exert a strong and positive contemporaneous effect on hazelnut exports, while their lagged values display significant negative effects, suggesting short-run price adjustments and correction dynamics. FDI has a positive and statistically

Table 6 Autoregressive distributed lag (1, 2, 4, 0, 1, 0, 0) model long-run estimation results (Authors' calculations)

Variables	Coefficient	Std. Error	t-Statistic	Prob.
FDI	–94,856.37	43,158.99	–2.197836	0.0337
PRC	200,734.2	25,974.48	7.728132	0.0000
PROD	0.190209	0.137183	1.386538	0.1731
REER	48,403.37	26,531.20	1.824394	0.0754
RSCA	9,463,861	4,868,957	1.943714	0.0588
TOT	–1599.802	1491.213	–1.072820	0.2896

VEXP Hazelnut exports, *FDI* Foreign direct investment, *PRC* Hazelnut export price, *PROD* Hazelnut production, *REER* Real effective exchange rate, *RSCA* Revealed symmetric comparative advantage, *TOT* Terms of trade

significant impact in the current period, with its lagged effect remaining marginally significant, indicating delayed transmission effects of investment inflows on export performance. The REER is found to be negatively and significantly associated with hazelnut exports in the short run, implying that currency appreciation adversely affects export competitiveness.

The error correction term—CointEq(-1)—is negative and highly significant at the 1% level, confirming the existence of a long-run equilibrium relationship among the variables and validating the ARDL specification. The estimated coefficient of –0.76 implies that approximately 76% of short-run deviations from long-run equilibrium are corrected within one period, indicating a relatively rapid adjustment process. Furthermore, the model demonstrates strong explanatory power, as reflected by a high adjusted R^2 value of 0.90, and overall statistical significance based on the F-statistic. These findings suggest that while hazelnut exports are sensitive to short-run price and exchange rate fluctuations, deviations from equilibrium are swiftly eliminated over time.

Within the ARDL framework, the short-run and long-run dynamics are derived from different components of the estimated model. While the long-run coefficients reflect the equilibrium relationship between the dependent and explanatory variables, the short-run dynamics are determined by the optimal lag structure selected according to information criteria. Consequently, not all explanatory variables necessarily appear in the short-run error correction representation if their lagged differences are found to be statistically insignificant or if the optimal lag length for a particular variable is zero.

In this study, variables such as PROD, the RSCA, and TOT primarily influence hazelnut exports through long-run structural and supply-side channels, rather than through short-run fluctuations. Therefore, these variables do not enter the short-run specification with statistically significant lagged differences. In contrast, variables such as PRC, FDI, and the REER exhibit more immediate adjustment effects and are thus captured in the short-run dynamics. This dis-

Table 7 Autoregressive distributed lag (1, 2, 4, 0, 1, 0, 0) model short-run estimation results (Authors' calculations)

Variables	Coefficient	Std. Error	t-Statistics	Prob.
D(FDI)	41,244.76	19,560.22	2.108604	0.0416
D(FDI(-1))	31,686.88	18,447.26	1.717701	0.0940
D(PRC)	121,668.0	7873.556	15.45274	0.0000
D(PRC(-1))	–62,563.71	9832.675	–6.362837	0.0000
D(PRC(-2))	–45,735.50	8756.269	–5.223172	0.0000
D(PRC(-3))	–38,408.37	8512.649	–4.511917	0.0001
D(REER)	–187,587.5	35,236.93	–5.323605	0.0000
C	–7014178.	938,315.1	–7.475291	0.0000
CointEq(-1)*	–0.756931	0.100946	–7.498387	0.0000
R-squared	–	0.916974	–	–
Adjusted R-squared	–	0.899495	–	–
F-statistics	–	52.46120	–	–
Durbin–Watson	–	2.057589	–	–
Akaike info criterion	–	24.86190	–	–
Schwarz criterion	–	25.21619	–	–
Hannan–Quinn criterion	–	24.99522	–	–

FDI Foreign direct investment, *PRC* Hazelnut export price, *REER* Real effective exchange rate, *C* Constant term, *CointEq(–1)* Error correction term

tinction is consistent with the theoretical expectations and the inherent properties of the ARDL methodology (Table 7).

The CUSUM and CUSUMSQ tests proposed by Brown et al. (1975) are widely used to assess parameter stability and to detect the presence of structural breaks in time-series models. In the presence of structural instability, dummy variables are typically introduced to account for such breaks. The conventional decision rule states that if the CUSUM and CUSUMSQ statistics remain within the 5% critical bounds, the null hypothesis of parameter stability cannot be rejected. As illustrated in Fig. 1a, b, the recursive estimates of both the CUSUM and CUSUMSQ statistics lie entirely within the 5% significance boundaries throughout the sample period. This finding indicates the absence of systematic parameter shifts and confirms the stability of the estimated coefficients. Accordingly, the error correction model does not exhibit structural instability over the reference period.

Conclusions

This study pursued two primary objectives. First, it aimed to evaluate the competitiveness of Türkiye's hazelnut sector over the period 1970–2020 using the revealed symmetric comparative advantage (RSCA) index. Second, it sought to examine the long-run and short-run relationships between Türkiye's hazelnut exports and key explanatory variables namely foreign direct investment (FDI), hazelnut export prices, hazelnut production, the real effective exchange rate (REER), the RSCA index, and terms of trade by employing the autoregressive distributed lag (ARDL) bounds testing approach to cointegration.

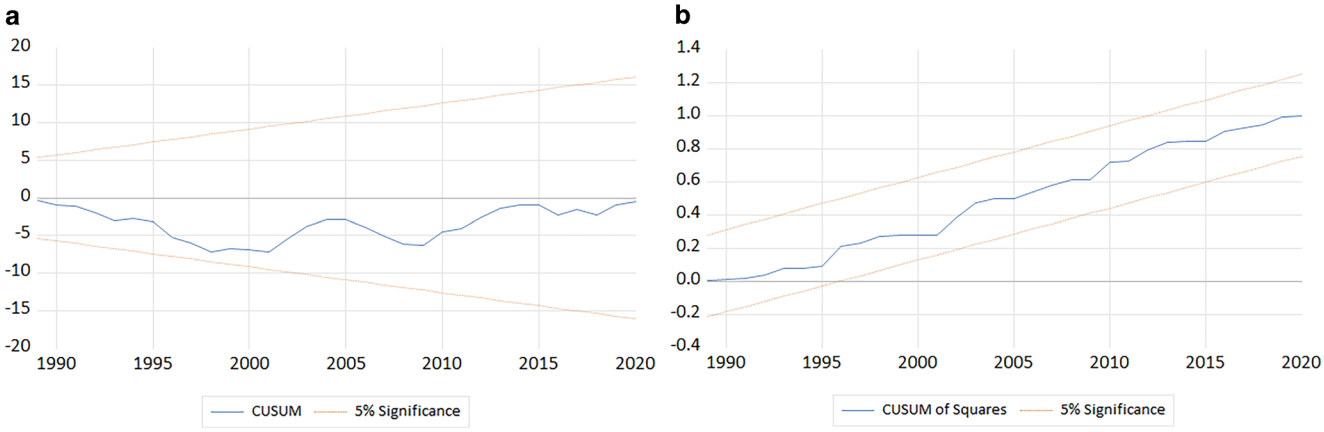


Fig. 1 Graphs of the cumulative sum (*CUSUM*) and CUSUM of squares tests

The results of the RSCA index confirm Türkiye's strong and persistent comparative advantage in the global hazelnut market, reflecting its dominant production capacity and established export structure. Despite this structural strength, the econometric findings indicate that export performance is shaped not only by production capacity but also by price dynamics, competitiveness, and macroeconomic conditions. Given Türkiye's leading position in global hazelnut production, analyzing the determinants of hazelnut exports constitutes a critical step in understanding the sustainability of this advantage.

Prior to the ARDL estimation, standard unit root tests were applied, and the mixed order of integration among the variables justified the use of the ARDL bounds testing methodology. The long-run estimation results reveal that hazelnut exports are significantly cointegrated with export prices, the RSCA index, and the real effective exchange rate, while hazelnut production and terms of trade do not exhibit statistically significant long-run effects. Export prices and competitiveness indicators exert positive long-run impacts on hazelnut exports, underscoring the importance of pricing strategies and sustained comparative advantage. In contrast, FDI is found to have a statistically significant but negative long-run effect, suggesting that FDI inflows into the sector may not be directly oriented toward export-enhancing activities.

The short-run dynamics further illustrate the sensitivity of hazelnut exports to price and exchange rate fluctuations. Export prices display a strong contemporaneous positive effect, while their lagged coefficients are negative and significant, indicating short-run adjustment mechanisms. FDI contributes positively to exports in the short run, although its impact weakens over time. The REER negatively affects hazelnut exports, implying that currency appreciation undermines export competitiveness. The error correction term is negative and highly significant, confirming the existence of a stable long-run relationship among the variables. The estimated adjustment coefficient suggests that approximately 76% of short-run disequilibria are corrected within one period, indicating a rapid convergence toward long-run equilibrium. Moreover, diagnostic statistics confirm the robustness and stability of the estimated model.

Overall, the findings demonstrate that FDI does not generate the expected positive long-run contribution to hazelnut exports, despite Türkiye's strong comparative advantage in the sector. This suggests that export performance depends more critically on effective price formation, competitiveness, and exchange rate stability than on capital inflows alone. From a policy perspective, these results highlight the need for targeted investment strategies that prioritize export-oriented activities, as well as coordinated policies linking production planning with export pricing and macroeconomic stability. Implementing such measures would support the sustainability of Türkiye's leading position in the global hazelnut market and enhance the effectiveness of its foreign trade strategy.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Alptekin Mert YILMAZ. The first draft of the manuscript was written by Alptekin Mert YILMAZ and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability The data that support the findings of this study are available from the corresponding author, [A.M.Y], upon reasonable request.

Competing interests

The authors declare no competing interests.

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